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Extended essay cover

Diploma Programme subject in which this extended essay is registered: World Studies

(For an extended essay in the area of languages, state the language and whether it is group 1 or group 2.)

Title of the extended essay: To what extent will ocean acidification have an impact on the marine life and on local communities around the Great Barrier Reef?

Candidate's declaration

This declaration must be signed by the candidate; otherwise a grade may not be issued.

The extended essay I am submitting is my own work (apart from guidance allowed by the International Baccalaureate).

I have acknowledged each use of the words, graphics or ideas of another person, whether written, oral or visual.

I am aware that the word limit for all extended essays is 4000 words and that examiners are not required to read beyond this limit.

This is the final version of my extended essay.

Supervisor's report and declaration

The supervisor must complete this report, sign the declaration and then give the final version of the extended essay, with this cover attached, to the Diploma Programme coordinator.

Name of supervisor (CAPITAL letters)

Please comment, as appropriate, on the candidate's performance, the context in which the candidate undertook the research for the extended essay, any difficulties encountered and how these were overcome (see page 13 of the extended essay guide). The concluding interview (viva voce) may provide useful information. These comments can help the examiner award a level for criterion K (holistic judgment). Do not comment on any adverse personal circumstances that may have affected the candidate. If the amount of time spent with the candidate was zero, you must explain this, in particular how it was then possible to authenticate the essay as the candidate's own work. You may attach an additional sheet if there is insufficient space here.

approached her extended essay with maturity and independence. She displayed a positive attitude throughout the experience and organised her time very wisely.

was always passionate about her topic and did her very best to gather resources that were not easy to obtain. The lack of research existing on the possible economic consequences of the acidification of the ocean near the Great Barrier Reef made her research both challenging and interesting. She explored with great insight the environmental aspect of the consequences.

At the end of the project, she spent some time discussing with me ethical responsibility of the human community in the Ocean's acidification. She demonstrated a very intelligent approach and understood the complexity of balancing economical development with preservation of natural resources.

This declaration must be signed by the supervisor; otherwise a grade may not be issued.

I have read the final version of the extended essay that will be submitted to the examiner.

To the best of my knowledge, the extended essay is the authentic work of the candidate.

I spent [4] hours with the candidate discussing the progress of the extended essay.

Assessment form (for examiner use only)

Criteria	Achievement level				
	Examiner 1	maximum	Examiner 2	maximum	Examiner 3
A research question	2	2		2	
B introduction	2	2		2	
C investigation	3	4		4	
D knowledge and understanding	3	4		4	
E reasoned argument	3	4		4	
F analysis and evaluation	3	4		4	
G use of subject language	3	4		4	
H conclusion	2	2		2	
I formal presentation	2	4		4	
J abstract	1	2		2	
K holistic judgment	3	4		4	
Total out of 36	27				

Extended Essay

To what extent will ocean acidification have an impact on the marine life and on the local communities around the Great Barrier Reef?

"Ocean acidification is unique among human impacts on the marine environment in its persuasiveness and persistence"
-Antarctic Climate and Ecosystems CRC, 2008

Abstract word count: 249
Essay word count: 3571

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Abstract

The following research aims at identifying the extent to which ocean acidification will have an impact on the marine life and the local communities around the Great Barrier Reef. The investigation is done as part of the 'World Studies' option, focusing particularly on the environmental and economic aspects from an IB Biology and IB economics standpoint.

Though there was limited data available since the effects of ocean acidification on coral reefs are still not completely conclusive, the exploration includes the effects on the calcification of corals, the bleaching of corals, reef growth as a whole, the biodiversity and on the food web. The possibility for adaptation and evolution are discussed to the scope that is possible.

The inquiry then goes on to evaluate how these environmental impacts may affect the local communities economically. It examines how there might be changes in the attractiveness of the Great Barrier Reef to tourists, how the fishing industry might be impacted and how native inhabitants of the area will have to deal with the changes in the environment.

The conclusions drawn from the research are that the extent to which the environment will face changes is much more significant as compared to the local economy and that the impacts on the economy are directly dependent on the scale of the environmental impacts. The consequences on the environment due to ocean acidification, being a result of the increase in atmospheric carbon dioxide, will depend on whether the carbon emissions increase at same rate or not.

Introduction

The Great Barrier Reef (GBR) is the world's largest coral reef system and occupies an area of approximately 344'400 km^2 (Australian Government Great Barrier Reef Marine Park Authority). It is located off the coast of Queensland, Australia, and is estimated to be about 500'000 years old (Zimmerman). The Great Barrier Reef is built up of billions of coral polyps and includes approximately 2'500 individual reefs, each providing habitat to a wide range of marine organisms.

The reef houses a third of the world's soft coral species, over 400 species of hard coral, 3'000 mollusc species, thousands of different sponge species, as well as 1'500 species of fish (WWF). Many of these species are endemic to the Great Barrier Reef and all of them interact to form an ecosystem of incredible biodiversity. The reef's significance is nevertheless not limited to its rich marine life, but is also of great importance to the human community of the area. It is estimated that approximately $5.4 billion is supplied to the Australian economy annually and about 63,000 people are employed because of reef-related industries (WWF). The reef's industries and inhabitants of the nearby area rely on the continuing well-being of the environment.

Various studies have suggested that around the region of the Great Barrier Reef (GBR), the rate of accumulation of calcium salts in marine organisms' tissues, known as the calcification rate, has recently decreased significantly (Hoegh-Guldberg). The calcification rate of these organisms is vital to their skeletal growth and reef growth and research suggests it has declined by 14.2% since 1990 (De'ath). Such sudden changes in the calcification rates have never been recorded previously and several studies, such as the investigation 'Impacts of ocean acidification on marine fauna and ecosystem processes', published in the 65th issue of the ICES Journal of Marine Science, argue that this decrease can be directly associated with ocean acidification (Fabry). Ocean acidification is the uptake of atmospheric carbon dioxide by the oceans, causing a decrease in their pH. This change in the ocean's chemistry increases the area where calcium carbonate structures begin to dissolve.

This paper will examine to what degree ocean acidification may have played a role in the changes in calcification rates and focus on the future consequences of these changes. The exigency of studying the effects that this increased ocean acidification has on marine life is based on the fact that many of the marine species present in the GBR are of substantial conservation significance. Atmospheric CO_2 levels are continuing to rise and this could have a detrimental impact on the ecology as well as an economic impact to the local communities around the Great Barrier Reef.

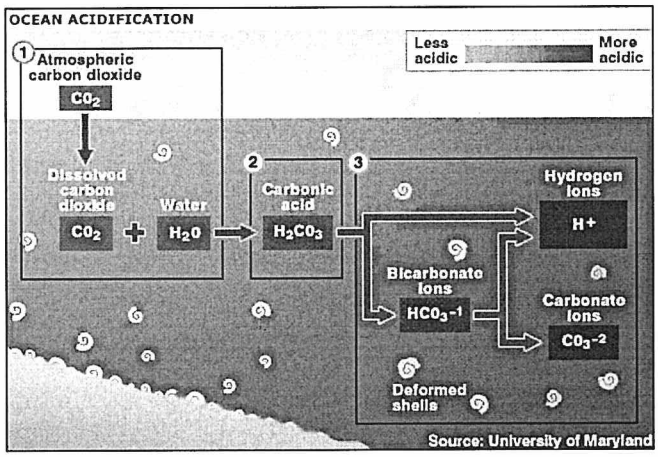
The essay will be part of the 'World Studies' option, looking at the problem from two different lenses to grasp a better understanding of the topic and its implications.

- Firstly, the environmental results of ocean acidification on the marine life of the GBR will be investigated using principles of the IB Diploma Programme subject 'Biology'. Here the focus will be on the effects on corals and how this impacts the ecology and environment.
- Later, to make sense of the gravity of the issue, the repercussions on the local communities will be dealt with from an IB 'Economics' standpoint.

Although the investigation focuses on the GBR, its marine life and the peoples of that particular region, the concern and the concepts can certainly be applied to a variety of other environments and marine life dependent communities around the world.

Ocean Acidification

The uptake of atmospheric carbon dioxide by the oceans causes water (H_2O) and carbon dioxide (CO_2) to react and form carbonic acid (H_2CO_3). This increases the concentration of hydrogen ions (H^+) and since the concentration of hydrogen ions determines the acidity of a solution, it causes a change in the pH of the ocean. The greater the concentration of hydrogen ions in the ocean, the lower the pH of the ocean. Therefore the increase in atmospheric CO_2 directly impacts the acidity and pH of the ocean. The following diagram shows the process of ocean acidification more visually:



http://oceanleadership.org/acidifying-oc 1

Marine Carbonate Chemistry

There is a natural boundary in seawater that separates the more acidic lower layers of the ocean from the less acidic upper layers. This is known as the saturation horizon. Its depth can vary from a few hundreds to a few thousands of meters below the surface, depending on the ocean and which part of the ocean is being looked at. The saturation horizon shows the depth of seawater below which calcium carbonate ($CaCO_3$) dissolves.

Calcifying organisms must live above the saturation horizon and therefore closer to the surface since they produce $CaCO_3$ shells. An increase in the acidity of the oceans raises this saturation horizon closer to the surface, which could have detrimental consequences for organisms that produce external $CaCO_3$ shells and plates. As the saturation horizon nears the surface, there could be both reduced $CaCO_3$ production by organisms and dissolution of calcified structures.

The marine organisms that are most commonly associated with forming shells or plates of $CaCO_3$ by calcification are molluscs, corals, echinoderms, foraminifera, phytoplankton and calcareous algae. A decrease in calcification will weaken such organisms and the reef structures in general. Many coral reefs even require calcified structures for survival and thus the effects of a lowered oceanic pH are rather drastic. The stages of early development and reproduction in the life cycle of calcifiers are believed to be the most vulnerable to environmental changes and are also arguably the most important. Decreased calcification rates at the early stages of development affect their fitness and increase their mortality. Cumulative effects across several stages of the calcifiers life cycle may even lead to the extinction of specific deep-sea species. Besides the physiological stresses caused by reduced calcification, adult calcifiers with blood are increasingly exposed to hypercapnia, a condition that results in excessive carbon dioxide in the bloodstream.

Although the tolerance to high CO_2 levels is species-specific, most organisms can be expected to face some threat to their population size and dynamics as well as the structure of their community. Entire coral reef systems, such as ones present in the Great Barrier Reef are hence prone to significant decline as a result of surface ocean acidification.

Environmental impacts

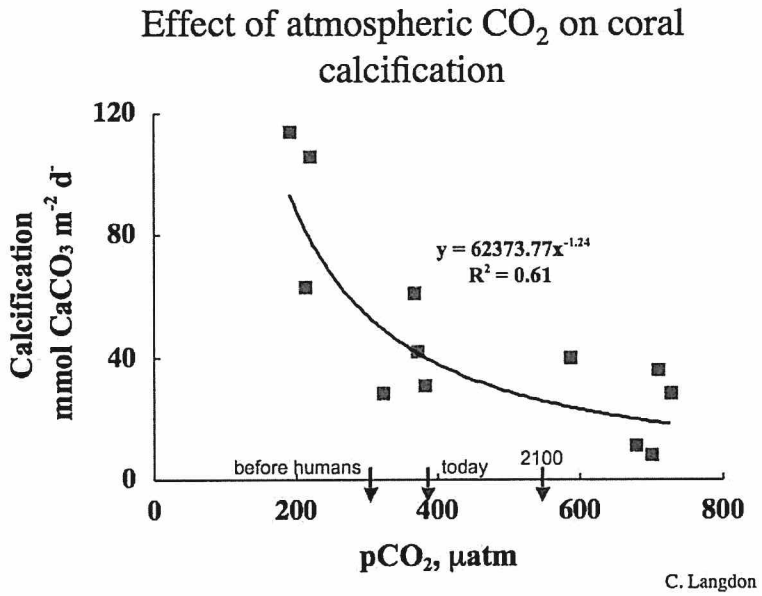
How an abundance of CO_2 impacts individual corals

In order to understand the environmental impact on the reef as a whole, it is necessary to assess the impact specifically on corals, especially in the context of the Great Barrier Reef, which is world's largest coral reef system (UNEP World Conservation Monitoring Centre).

Numerous studies have been published addressing the fact that in the past few decades, marine systems have faced tremendous difficulty coping with the increased atmospheric temperature. It was however only recently discovered that the increase in the CO_2 concentration of the oceans has a similar or even worse effect. The decrease in the pH of water is not necessarily lethal to corals, but it does seem to be reducing the ability for coral larvae to develop into juvenile colonies (Clinton). This is because (as mentioned previously), the effects of ocean acidification are particularly damaging to calcium carbonate production.

The extent to which the calcification rates are declining is quite unsettling. A report from two regions of the Great Barrier Reef done in 2008 shows that over the previous sixteen years, the calcification rates in the Porites, a significant genus of stony coral, have gone down by more than 21% (Cooper). This means that if future acidification continues at the same rate, then there will be a faster decrease in the calcification rates.

A series of experiments performed at The Lamont–Doherty Earth Observatory (LDEO) is a research unit of Columbia University by Chris Langdon, show that the calcification of several coral species had a clear trend when plotted against the partial pressure of carbon dioxide. This was what the trend looked like:



https://www.e-education.psu.edu/earth540 1

But how significant is the decrease in calcification rates? The calcification of an organism is absolutely vital. The carbonate structures in the organism itself serve as a framework for the coral or as an exoskeleton, which serves as the most basic form of protection. These structures make them less vulnerable to erosion and dissolution. Any decrease in calcification rates can compromise the competitive fitness of the organisms affected. A weakening of the calcareous structures is harmful not only to the coral itself, but may also weaken reef frameworks as a whole.

A difficulty that arises when studying how ocean acidification affects calcification rates is that most research that is done focuses on how an elevated temperature affects corals. Much of the data does not properly account for the role that ocean acidification has played in calcification rates. This is because calcification is still not completely understood and the effects of ocean acidification on the physiology and fitness of corals in the long-term are still not conclusive.

To assess the environmental impact of ocean acidification on marine life, it is important to recognize that the

damage that is done to the individual corals leads to a weakening of coral skeletons and reef structures in general. The Great Barrier Reef absolutely requires calcified structures to survive and hence sure to suffer from significant damage due to ocean acidification.

Another damage that ocean acidification has had on corals is that is aggravates coral bleaching due to thermal stress. Coral bleaching refers to the expulsion or loss of algal pigmentation, which results in a whitening of the coral. Though this effect is not necessarily lethal, it puts the organism under more stress, hence increasing the possibility of mortality.

Effects on the ecosystem and the food web

Photosynthetic marine organisms such as phytoplankton make up almost 99% of organic matter that is used by marine food webs (Jarrold). Phytoplanktons are also calcareous organisms and hence are affected by ocean acidification in a similar way as corals. Most of these organisms or matter produced by these organisms are then consumed by other microorganisms, which are in turn consumed by multicellular organisms. Therefore even those organisms that are further away in the food web and not directly affected by ocean acidification will experience a change due to the general change in carbon chemistry. In addition to the food web, such organisms are vital in the marine ecosystem because they serve as habitats and breeding grounds and also recycle nutrients.

Both the damage done to physiology and competitive fitness of organisms that are directly affect by ocean acidification and the potential gaps in the food web raise the following question: is it possibly that this could give non-calcifying organisms an evolutionary and ecological advantage? Or will calcifying organisms evolve quickly enough to adapt?

Although there is not much data to work from, the only experiments done on possible adaptation were on species that are rapidly reproducing, in order to be able to test across several generations. The results of these tests were however not very promising and do not show any evidence of potential adaptation and evolution resulting due to ocean acidification. One report that has been published on the adaptation and evolution of marine organisms was done by Collins and Bell in 2004. Their tests were done on microscopic algae called Chlamydomonas. The algae were grown in conditions at three times the present CO_2 concentration for numerous generations and although the algae did undergo harmful changes, none of the genetic mutations showed signs of adaptation. Although several mutants developed, poor growth was observed both in the mutants and the normal algae.

There is therefore a possibility that non-calcifying organisms may dominate and then end up replacing the organisms that are adversely affected by ocean acidification in the food web.

Another factor that needs to be considered is the possibility of a loss in biodiversity. Lower calcification rates mean that it will be more difficult to build frameworks that are able to be the habitat for thousands of different species (Reaka-Kudla). This was already the case in geologic history, where there is evidence of mass extinction events, some of which had a relationship to changes in the pH of oceans. One specific example would be about 55 million years ago, when there was a steep rise in the ocean's carbon dioxide level after a huge methane release. This resulted in the extinction of several benthic forminifera species (Zachos). So, taking into consideration the fact that the reef structure will be weakened and what is known from past events, it is quite possible that biodiversity will soon diminish in the GBR.

Impacts on local communities

Though it appears as though ocean acidification will only have adverse effects on the marine life of the Great Barrier Reef, the people living around and close to the area will have to deal with some of these consequences as well.

The Great Barrier Reef itself is said to generate a total of $5.1 billion a year (Great Barrier Reef Marine Park Authority), according to a 2005 estimate by the Great Barrier Reef Marine Park Authority. This figure includes the inflow of money from the approximately two million coral-viewing visitors that it gets each year and the entire infrastructure that is necessary to support this. The marine tourism industry that manages these visits is the biggest industry of the area.

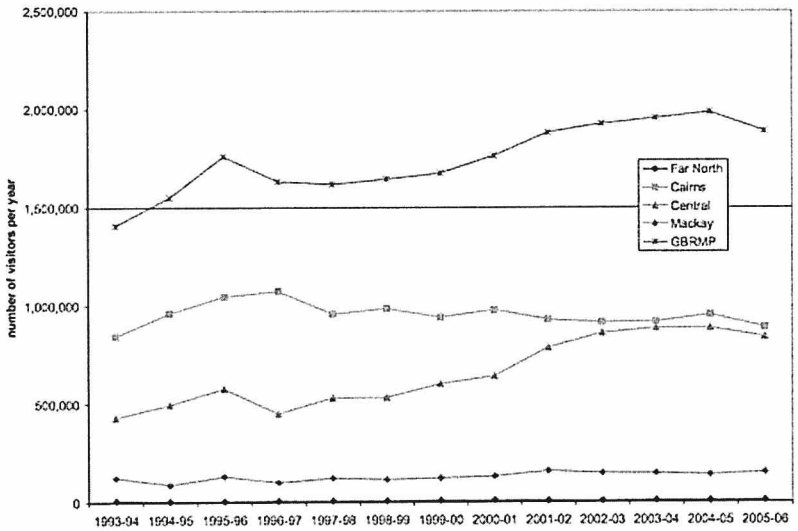
Hence the existence and the biodiversity of the GBR are absolutely crucial for the economic stability of the area. Outlined are some of the possible socio-economic impacts of ocean acidification.

Commercial activities

A lot of coral reefs around the world have public good characteristics (goods that are non-rivalrous non-excludable). This consequently leads to the coral reefs being undervalued. However the Great Barrier Marine Park Authority has decided to limit its open-access nature in order to preserve the reef and to generate profits that in turn can fund research. This is the sort of approach that has resulted in the GBR being a major contributor to the welfare of the local population, where otherwise opportunities for business are limited.

The industries revolving around the GBR, such as tourism and fishing, contribute billions of dollars each year and are been the greatest contributors to the local economy. This has been part an integral part of the history of the area where since the 1890s Green Island has been on of the prime destinations for cruises (Greatbarrierreef.org).

Reef dependent businesses may experience significant economic impact due to the potential dissolution of marine species. Continuing erosion and storm damage that is caused by the weakening of the reef, as well as a loss in biodiversity and the lowered attractiveness due to coral bleaching, could lead to a decline in the interest in the main activities, such as diving, snorkeling, and viewing, which would in turn lead to a further decline in the demand for many other goods and services offered at the GBR. The wealth associated with the present-day diverse ecosystems may soon be subject to devaluation. In 2003, the marine tourism industry alone was estimated to generate $4.2 billion per annum. Though the number of visitors has been known to rise steadily from 1996, there was a reduction of around 95,000 people visiting the GBR in 2005-06, especially significant in the region of Cairns and Central. This slight decline of visits can be seen in this graph:



Source: GBRMPA, February 2007, with 2005-06 data understood to be substantially complete.

Though this decrease may not be directly associated with and a direct result of ocean acidification, a lack in interest of tourists will only increase if corals are bleached and less diverse. As this income declines, the funds available to sustain the area would be limited and the largest commercial activity in the Great Barrier Reef region would be less profitable.

It is however still possible, that a global decline in coral reefs and the biodiversity of the marine environment may lead to more tourists being attracted to this industry out of fear that ocean acidification and elevated temperatures will lead to the extinction of specific marine organisms.

A smaller, yet still significant industry that is dependent on the GBR is the fishing industry. The fishing industry is estimated to be worth just below one billion dollars per annum (Great Barrier Reef Marine Park Authority). There are about 2000 people employed in the industry, but there are many more people that go fishing for recreational or tradition reasons (Great Barrier Reef Marine Park Authority). The high importance of specific individual organisms in the fishing industry leave the fishing industry more vulnerable to damage as a result of a loss in biodiversity and gaps in the food web, as opposed to the tourism industry, where tourists are interested in the reef as whole.

Social impact

Besides the monetary value, the GBR is also a site that is valuable to the locals in many other ways.

The first most obvious societal impact is unemployment. It is estimated that there are approximately 63,000 leisure and tourism jobs due to the Great Barrier Reef (Great Barrier Reef Cruises). There is a wide range of tourism-related and reef-related jobs in the area. This is because several of the surrounding islands are tourist resorts offering day tours and snorkeling. There are educational and recreational ships, aircrafts, shops that sell and rent sportswear (Greatbarrierreef.org) and all the other touristic businesses that is common to all such touristic locations. If the revenue of any of these individual businesses goes down, there will not be enough opportunities to sustain the current level of employment. Unemployment leads not only to economic deprivation, but often also to social degradation. It is does not only decrease economic growth potential in the area; it is also related to increased crime and divorce rates. Unemployment is said to make people more vulnerable to health-related problems and lower the life expectancy.

Secondly, a decline in business and interest around the GBR will lead to a drop in real estate prices. This is because rent around the GBR and the tourism services are related and complementary goods. A fall in the value of land causes a reduction in the wealth of the local people and thus their willingness to spend goes down. This will once again hinder economic growth, which in turn could lead to unemployment to dropping even further.

Another social implication that ocean acidification might have is that the protection of the coast from waves and storms will be weakened. This could result in coastal erosion and possibly an increase in storm damage, which would mean fewer activities could take place around the area.

Cultural consequences are also very likely to appear. The reef is known to be used by the aboriginal Australians and the Torres Strait Islanders. These people settled here 40,000 and 10,000 years ago, respectively. Many of their cultural and spiritual activities require the Great Barrier Reef to be as diverse as it is now. In their aboriginal culture, it is believed that after death a person's spirit may return in the form of a human, an animal or a plant. Many marine species are therefore considered ancestral beings and are of great value in their faith. A decrease in the diversity of marine species hence also has personal and religious implications.

Conclusion

Essentially, an understanding of the chemistry of how excess of carbon dioxide lowers the pH of the oceans is required in order to be able to understand the impact that an increase in CO_2 has on the calcification rates of the organisms around the Great Barrier Reef. This includes not only the effects on corals, but on all calcifying organisms. Some specific organisms around the GBR have already faced a major decline in calcification rates. This means that the ecosystem of the region will soon be subject to change, which could have a detrimental impact on the biodiversity as well. However the effects are not limited to the environment, but can in turn impact the economy of the area as well. The large sums that reef-related businesses bring in annually could decline and this could have social implications in terms of unemployment and reduced wealth.

The reason for a greater focus on the environmental impacts as compared to the economic impacts is due to the fact that the economic impacts are purely a consequence of the changes that occur to the environment. It is also more difficult to evaluate how changes in the environment will impact the economy, since the degree of these changes is still inconclusive and since interest in the Great Barrier Reef could increase as people worry about the possibility of the extinction of specific organisms.

The extent to which marine life and the local communities will be impacted depends on how seriously the ethical duty of preserving the reef is taken. Since ocean acidification is a direct result of an increase in the carbon dioxide of the atmosphere, it is important that global carbon emissions must be reduced. Also, methods by which the pH can be increased, such as using limestone to raise the pH (Upton) need to be investigated and developed. This alone however is not enough. The Government of Queensland and the Great Barrier Reef Marine Authority need to ensure that the reef remains as diverse as it is now and take action in a sustainable manner. Funds need to be put into further research, especially since the effects of ocean acidification on corals are not yet properly understood. Most importantly, there needs to be an economic and social incentive to preserve the environment.

Bibliography

"Aboriginal & Torres Strait Islander Culture & Dugongs and Turtles." *Great Barrier Reef Marine Park Authority.* Australian Government, n.d. Web. 23 May 2013. <http://web.archive.org/web/20070928021214/http://www.gbrmpa.gov.au/corp_site/key_issues/conservation/natural_values/indigenous>.

Access Economics Pty Ltd (2005). "Measuring the economic and financial value of the Great Barrier Reef Marine Park". 13 August 2013. (PDF)

Clinton E. Hare et al. , "Consequences of Increased Temperature and CO2 for Phytoplankton Community Structure in the Bering Sea," Marine Ecology Progress Series, v. 352 (2007), p. 14.

Collins, Sinead, Dieter Sultemeyer, and Graham Bell. "Changes in C Uptake in Populations of Chlamydomonas Reinhardtii Selected at High CO2." *Plant, Cell and Environment* 29.9 (2006): 1812-819. Print.

Cooper, Timothy F. , Glenn De'ath, Katharina E. Fabricius, and Janice M. Lough. *Declining Coral Calcification in Massive Porites in Two Nearshore Regions of the Northern Great Barrier Reef.* Publication no. 1365-2486. 2007. 01520. 3rd ed. Vol. 14. Townsville: Australian Institute of Marine Science, 2007. Print.

De'ath, Glenn, Janice M. Lough, and Katharina E. Fabricius. *Declining Coral Calcification on the Great Barrier Reef.* Rep. Vol. 323. Townsville: Sciencemag. org, 2009. Web. SCIENCE.

Fabry, V. J., B. A. Seibel, R. A. Feely, and J. C. Orr. "Impacts of Ocean Acidification on Marine Fauna and Ecosystem Processes." *ICES Journal of Marine Science* 65.3 (2008): 414-32. Print.

"Working Together Today for a Healthier Reef Tomorrow. . . " *Facts about the Great Barrier Reef.* Australian Government Great Barrier Reef Marine Park Authority, n. d. Web. 04 July 2013. <http://www. gbrmpa. gov. au/about-the-reef/facts-about-the-great-barrier-reef>.

Great Barrier Reef Marine Park Authority. *Great Barrier Reef Outlook Report 2009 : In Brief.* Publication no. 9781876945916. N. p. : Great Barrier Reef Marine Park Authority, 2009. Print.

"The Great Barrier Reef. " *WWF.* N. p. , n. d. Web. 23 Oct. 2013. <http://www. wwf. org. au/our_work/saving_the_natural_world/oceans_and_marine/priority_ocean_places/great_barrier_reef/>.

Great Barrier Reef Marine Park Authority. "Aboriginal & Torres Strait Islander Culture & Dugongs and Turtles". Archived from the original on 28 September 2007. Retrieved 13 September 2013.

Hoegh-Guldberg, O. , P. J. Mumby, A. J. Hooten, R. S. Steneck, P. Greenfield, E. Gomez, C. D. Harvell, P. F. Sale, A. J. Edwards, K. Caldeira, N. Knowlton, C. M. Eakin, R. Iglesias-Prieto, N. Muthiga, R. H. Bradbury, A. Dubi, and M. E. Hatziolos. *Coral Reefs Under Rapid Climate Change and Ocean Acidification.* Publication no. 1152509. 5857 ed. Vol. 318. N. p. : n. p. , 2007. Print.

Jarrold, Michael. "How Will Ocean Acidification Affect Marine Photosynthetic Organisms? A Review." *The Plymouth Student Scientist* 617-634 5.2 (2012): n. pag. Print.

J. C. Zachos et al. , "Rapid Acidification of the Ocean During the Paleocene-Eocene Thermal Maximum," Science, v. 308 (2005): 1611-1615.
[1] Great Barrier Reef Marine Park Authority (2005). "Protecting Biodiversity Brochure 2005". Archived from the original on 17 July 2013.

"The Great Barrier Reef. " *WWF.* N. p. , n. d. Web. 31 May 2013. <http://www. wwf. org. au/our_work/saving_the_natural_world/oceans_and_marine/priority_ocean_places/great_barrier_reef/>.

Langdon, Chris, Taro Takahashi, Colm Sweeney, Dave Chipman, John Goddard, Francesca Marubini, Heather Aceves, Heidi Barnett, and Marlin J. Atkinson. *Effect of Calcium Carbonate Saturation State on the Calcification Rate of an Experimental Coral Reef.* Publication no. 1999GB001195. 2nd ed. Vol. 14. N. p. : n. p. , 2012. Print.

Kleypas, Joan, and Kimberly Yates. "Coral Reefs and Ocean Acidification." *Oceanography* 22.4 (2009): 108-17. Print.
"Calcification." *Coral Reefs:*. N.p., n.d. Web. 15 Sep. 2013. <http://www.reefresilience.org/Toolkit_Coral/COAb1_Calcification.html>.

R. Albright et al. , "Effect of Aragonite Saturation State on Settlement and Post-Settlement Growth of Porites astreoides Larvae," Coral Reefs, v. 27, no. 3 (2008): 485-490.

"Reef Tourism." *Greatbarrierreef.org* (n.d.): n. pag. *Tourism in the Region.* Web. 14 July. 2013. <http://www.greatbarrierreef.org/tourism_overview.php>.

T. F. Cooper et al. , "Declining Coral Calcification in Massive Porites in Two Nearshore Regions of the Northern Great Barrier Reef," Global Change Biology, v. 14 (2008): 529-538.

UNEP World Conservation Monitoring Centre (1980). "Protected Areas and World Heritage – Great Barrier Reef World Heritage Area". Department of the Environment and Heritage. June 27th 2013.

Upton, Harold F., and Peter Folger. "Ocean Acidification." *Congressional Research Service* (n.d.): n. pag. Web. 6 June 2013. <http://www.fas.org/sgp/crs/misc/R40143.pdf>.

Zimmermann, Kim An, Mrs. "Great Barrier Reef: Facts, Location & Animals. " *LiveScience. com.* LiveScience, 14 Sept. 2012. Web. 03 June 2013. <http://www. livescience. com/6290-great-barrier-reef. html>.

"10 Interesting Facts about the Great Barrier Reef." *Great Barrier Reef Cruises.* N.p., n.d. Web. 14 June. 2013. <http://www.thegreatbarrierreefcruises.com/10interestingfactsaboutgreatbarrierreef.html>.